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## Characterization and Nonlinear Interaction of Shear Alfvén Waves in the Presence of Strong Tearing Modes in Tokamak Plasmas

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Shear Alfvén waves (SAWs) are very common in magnetized plasmas both in space and laboratory. In present-day fusion and future burning plasmas, SAWs are easily excited by fast particles and energetic alpha particles produced by nuclear fusion reactions. SAWs can cause the loss and redistribution of energetic particles so that affect plasma performance or damage the plasma wall. The physics of SAWs is an intriguing but complex area of research. Meanwhile, it is important of studying axi-symmetry mode and nonlinear mode coupling. The axi-symmetry mode such as zonal flows (ZFs) and geodesic acoustic mode (GAM) is associated with the plasma turbulence and confinement. The role of nonlinear mode coupling is generally important in determining the mode excitation, saturation or damping. The SAWs can interact nonlinearly, and lone wave packets can suffer decay instabilities including the parametric and modulational those, where the pump decays into a daughter SAW, ion acoustic wave or ZFs.

In the paper, we will report the excitation and generation of the AEs and two kind axi-symmetry magnetic activities in the presence of strong tearing modes (TMs) during NBI on HL-2A, and present that there exists the intense nonlinear interactions between AEs and low-frequency MHD modes, and develop a theory to explain this experimental phenomenon. Detailedly, in the presence of large magnetic island, the TAEs or BAEs are driven by the energetic-particles. The AEs then are modulated by the strong TMs, resulting in the subsequent generation of Alfvénic sidebands including the co-/counter-propagating AEs, and two kind axi-symmetry magnetic activities with  $n=0$  have been observed in the presence of strong tearing modes. One kind has been identified, and belongs to EGAM. The density fluctuations induced by EGAM are firstly measured by microwave Doppler reflectometers. Another kind is found for the first time, its frequency lies in the range of TAE frequency. The Fourier bicoherence analysis suggests these axi-symmetry modes are generated by the nonlinear mode coupling via the decay process between AEs and low-frequency MHD modes. The experimental results indicate that the nonlinear mode coupling is one of mechanisms of the energy cascade in energetic-particle turbulence or Alfvén turbulence.

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